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Cow comfort in tie-stalls: Increased depth of shavings or straw bedding increases lying time

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ABSTRACT

Over half of US dairy operations use tie-stalls, but these farming systems have received relatively little research attention in terms of stall design and management. The current study tested the effects of the amount of 2 bedding materials, straw and shavings, on dairy cattle lying behavior. The effects of 4 levels of shavings, 3, 9, 15, and 24 kg/stall (experiment 1, n = 12), and high and low levels of straw in 2 separate experiments: 1, 3, 5, and 7 kg/stall (experiment 2, n = 12) and 0.5, 1, 2, and 3 kg/stall (experiment 3, n = 12) were assessed. Treatments were compared using a crossover design with lactating cows housed in tie-stalls fitted with mattresses. Treatments were applied for 1 wk. Total lying time, number of lying bouts, and the length of each lying bout was recorded with data loggers. In experiment 1, cows spent 3 min more lying down for each additional kilogram of shavings (11.0, 11.7, 11.6, and 12.1 ± 0.24 h/d for 3, 9, 15, and 24 kg/stall shavings, respectively). In experiment 2, cows increased lying time by 12 min for every additional kilogram of straw (11.2, 12.0, 11.8, and 12.4 ± 0.24 h/d for 1, 3, 5, and 7 kg/stall of straw, respectively). There were no differences in lying behavior among the lower levels of straw tested in experiment 3 (11.7 ± 0.32 h/d). These results indicated that additional bedding above a scant amount improves cow comfort, as measured by lying time, likely because a well-bedded surface is more compressible.

Key words: bedding, cow comfort, tie-stall, behavior

INTRODUCTION

Housing for dairy cattle is receiving a growing amount of attention in both the scientific literature and in the dairy industry. Dairy cattle generally spend 8 to 16 h/d lying down and there is growing evidence that lying is a priority for cows. For example, cows kept in tie-stalls will complete an operant task to maintain lying times of 12 or more hours per 24 h (Jensen et al., 2005). If lying behavior is disturbed for several hours per day, cattle will choose to lie down rather than feed (Metz, 1985; Munksgaard et al., 2005).

There is increasing evidence that bedding plays a key role in maintaining and promoting cow comfort, as measured by health and behavior. For example, bedding plays an important role in the development, prevalence, and severity of leg injuries. Cows moved from pasture to scantily bedded mattresses will quickly (within 3 to 6 wk) develop hock lesions (Mowbray et al., 2003), and lying surface is an important risk factor for lesions (Weary and Taszkun, 2000; Wechsler et al., 2000; Fulwider et al., 2007). Front legs are also affected by the lying surface. Cows kept on concrete were 3 times more likely to have swollen carpal joints compared with cows kept on rubber mats (Rushen et al., 2007), and cows housed on abrasive surfaces such as recycled sand were more likely to experience hair loss and swelling in the carpal joints (Fulwider et al., 2007). Injuries to both the front and hind legs were lowest in compost or straw systems compared with stalls fitted with mattresses or concrete, respectively (Fulwider et al., 2007; Schulze Westerath et al., 2007).

The amount of bedding influences lying time and structure of lying bouts throughout the day. Lying times were reduced when dairy cattle were housed without bedding (Haley et al., 2001; Rushen et al., 2007). In addition, lying times decline when less bedding is used. In sand-bedded free stalls, every 1-cm decline in bedding depth reduced lying time by 10 min/d (Drissler et al., 2005). With sawdust-bedded mattresses, lying time decreased 12 min/d for every 1-kg reduction in sawdust use (Tucker and Weary, 2004). The softness or compressibility of the lying surface may underlie the behavioral response to the amount of bedding. To date, studies on this topic have measured the amount of bedding by weight or depth. Although weight and depth are useful descriptors from an experimental perspective

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(i.e., repeatable), these measures provide little insight into which physical feature of bedding is important to dairy cattle.

Specific animals may be disproportionately affected by bedding levels. Heavy or large cows may perceive the softness of the lying area differently than smaller cows. Cows often respond to scantily bedded stalls by lying down less often (Tucker and Weary, 2004), perhaps because of the considerable weight placed on the knees during the transition from standing to lying. Thus, the hypothesis was that the comfort of heavy cows would be more affected by bedding levels than would that of lighter cows.

Much of the research has focused on free stalls, but many producers use tie-stalls to house cows (63% of US dairy operations; USDA, 2007) and there are considerable problems with injuries in these systems (Zurbrigg et al., 2005). The type of bedding used in both free- and tie-stalls varies with geographic region and availability; thus, 2 commonly used materials, straw and wood shavings, were compared. The objective was to evaluate how the amount and compressibility of these bedding materials affected the lying behavior of cows housed in tie-stalls.

MATERIALS AND METHODS

The study was conducted in the tie-stall dairy facility located at Agriculture and Agri-Food Canada's Research Centre in Lethbridge, Alberta, Canada. All cows were cared for under the guidelines established by the Canadian Council on Animal Care (1993).

Experiments 1 and 2

Kiln-dried shavings were used as the bedding source in experiment (**Exp.**) 1 and chopped straw was used in Exp. 2. Twelve lactating cows were randomly assigned to each experiment; 6 primiparous (mean ± SD; BW, 621 ± 83 kg; DIM, 107 ± 28) and 6 multiparous (BW, 727 ± 29 kg; DIM, 162 ± 55) in Exp. 1 and 7 primiparous (BW, 645 ± 78 kg; DIM, 164 ± 57) and 5 multiparous (BW, 666 ± 32 kg; DIM, 166 ± 19) in Exp. 2. The range of BW was 538 to 772 kg in Exp. 1 and 543 to 794 kg in Exp. 2. In each experiment cows received 4 levels of bedding over time; 1, 3, 5, and 7 kg/stall of straw in Exp. 1 (0.4, 1.3, 2.1, and 2.9 kg/m^2) and 3, 9, 15, and 24 kg/stall of shavings in Exp. 2 (1.3, 3.8, 6.3, and 10.0 kg/m^2). The range of bedding levels was chosen to reflect the range observed on commercial farms. The lowest levels barely covered the mattresses at the base of the stall, whereas the highest level of bedding provided an extremely well bedded option. Each cow was tested with each bedding level for 1 wk. Treatment was assigned randomly within the constraint that the number of cows on each treatment was equal and balanced across time.

The stalls measured 180 cm long × 132 cm wide and were fitted with mattresses (Cozy Cow, Roth Manufacturing Co., Loyal, WI). The stalls were bedded once daily. The bedding was applied to the stalls when the cows were let out of the barn for exercise from approximately 0730 to 0900 h. During the day, manure was routinely cleaned from the back of the stalls into an uncovered gutter behind the stalls, and any bedding that had moved laterally into the adjacent stalls was repositioned.

Lying times were monitored using Gemini Data Loggers (Gemini Inc., Chichester, UK; previously validated by O'Driscoll et al., 2008). Loggers were placed on the hind leg along the metatarsus bone and moved to the alternate leg on alternate weeks. This device used a mercury switch to determine leg orientation (standing versus lying) and was programmed to record position every 1 min. Before placing the logger on the cow, a band of Co-Flex Cohesive Flexible Bandage (Andover Coated Products Inc., Salisbury, MA) was placed around the leg. Petroleum jelly (Vaseline Intensive Care, Chesebrough-Ponds, Greenwich, CT) was spread over the bandage around the area where the logger was positioned to minimize irritation. Loggers were placed inside durable fabric pouches padded with 2 cm of foam, and wrapped around the leg with Velcro (Velcro Industries BV, Manchester, NH) and secured with cohesive bandage.

Cows were milked in their stalls twice daily at 0630 and 1630 h and milk production was recorded. All cows were fed a standard lactation TMR formulated using the Cornell-Penn-Miner system (CPM Dairy, Version 2.12; Cornell University, Ithaca, NY; University of Pennsylvania, Kennett Square, PA; and William H. Miner Agricultural Research Institute, Chazy, NY) for cows producing 35 kg/d of milk with 3.5% fat and 3.2% protein. Cows were fed for ad libitum intake (10% orts, DM basis) at 1300 h each day with feed pushed up or topped up 3 to 4 times during the day as required. This feeding routine was similar across treatments. Cows had free access to water.

Experiment 3

The third experiment tested lower levels of straw bedding. Six primiparous (BW, 580 ± 61 kg; DIM, 138 ± 33) and 6 multiparous (BW, 628 ± 37 kg; DIM, 87 ± 61) cows were each tested with 4 levels of chopped straw bedding: 0.5, 1, 2, and 3 kg/stall (0.2, 0.4, 0.8,

Table 1. Cows kept in tie-stalls bedded with 3, 9, 15, or 24 kg of shavings each morning (experiment 1)[1]

	Amount of shavings (kg/stall)						
Item	3	9	15	24	SEM	P_{weight}	$P_{compressibility}$
Compressibility (cm)	1.9	3.8	5.4	9.2	—	—	—
Average lying bout (min/bout)	55	56	55	56	1.9	0.637	0.637
Lying bouts (n/d)	12.5	13.2	13.3	13.8	0.61	0.163	0.169
Lying time (h/d)	11.0	11.7	11.6	12.1	0.24	0.004	0.004
Milk production (kg/d)	32.3	32.9	33.2	33.2	0.49	0.175	0.197

[1]Least squares means and SEM are presented. Treatments were applied within cow in a crossover design. The *P*-value for the linear term from the weight (kg/stall) and compressibility (cm) models are presented.

and 1.3 kg/m^2). None of the treatments fully covered the mattresses. The range of BW was 505 to 684 kg. All other aspects of this experiment were identical to Exp. 1 and 2.

Measures of Bedding Compressibility

To facilitate comparisons across our experiments, the compressibility of each level and type of bedding was measured. To assess compressibility, a stainless steel bowl (diameter of 254 mm at the top and 120 mm at the bottom) was placed on the bedded stall surface. A 100-kg (±2 kg) weight was then placed into the bowl for approximately 1 min. The bowl was removed and the depth of the bedding pack was measured before and after compression. The test was replicated twice within each stall and the average value reported in centimeters.

Statistical Analysis

Within each experiment, the time spent lying was summarized by treatment for each cow. Data were removed on days when cows were treated with antibiotics for mastitis, were in heat or bred, or were treated with any drug. Eighteen cow-days were removed from 8 cows in Exp. 1 for these reasons. In Exp. 2, 9 cows were affected, resulting in removal of 19 cow-days. Body weight information was lost for 1 cow each in Exp. 1 and 2. In Exp. 3, 1 multiparous and 1 primiparous cow were removed because of failure of the data loggers.

Data were analyzed by experiment using a GLM (SAS Institute, 1999). The model included terms for cow (11 df in Exp. 1 and 2; 9 df in Exp. 3), order of exposure to each treatment (3 df), and treatment (3 df). Linear (1 df), quadratic (1 df), and cubic (1 df) effects of level were examined using a contrast statement. Treatments were not evenly spaced; thus, the coefficients for each term used in the contrast statement were generated with PROC IML (SAS Institute, 1999). A second model was used to explore BW as a covariate. This model included terms for BW (1 df), cow (10 df in Exp. 1 and 2; 8 df in Exp. 3), treatment (3 df), and BW by treatment interaction (3 df). Both models were run twice, with treatment expressed as bedding weight (kg/stall) or bedding compressibility (cm). For Exp. 3, the compressibility model included only linear and quadratic terms because 0.5 and 1 kg of straw had the same level of compression. Least squares means and SEM from the weight of bedding model are presented.

RESULTS

In Exp. 1, cows spent more time lying down when more shavings were provided (Table 1). Lying times were lowest when only 3 kg/stall of shavings was used (11.0 h/d) and highest when 24 kg of shavings was provided (12.1 h/d). There were no differences in the number of lying bouts or the length of these bouts. Milk production averaged 32.9 kg/d regardless of treatment. Body weight did not influence any response to bedding level ($P \geq 0.358$).

In Exp. 2, cows spent more time lying down when stalls were bedded with more straw: 11.2 h/d versus 12.4 h/d for the 1- and 7-kg treatments, respectively (Table 2). Cows lay down more often when stalls had more bedding, increasing from 11 bouts/d for the 1-kg treatment to 13 bouts/d for the 7-kg treatment. Cows produced 32.7 kg milk/d regardless of treatment. Body weight did not influence any response to the amount of straw ($P \geq 0.401$).

In Exp. 3, there was no effect of treatment for any variable (Table 3) and no interaction with BW ($P \geq 0.128$).

Lying times increased more slowly in response to bedding weight when the material was shavings (Exp. 1; an increase of 3 min/kg) compared with straw (Exp. 2; 12 min/kg; Figure 1A). The response to treatment was much more similar when treatments were expressed in terms of compressibility; for every 1-cm increase in compressibility of the bedding, cows spent an additional 9 min lying in Exp. 1 and an additional 6 min lying in Exp. 2 (Figure 1B).

Table 2. Cows kept in tie-stalls bedded with 1, 3, 5, or 7 kg of straw each morning (experiment 2)[1]

Item	Amount of straw (kg/stall) 1	3	5	7	SEM	P_{weight}	$P_{compressibility}$
Compressibility (cm)	2.2	6.7	7.6	14.6	—	—	—
Average lying bout (min/bout)	63	61	60	60	1.5	0.152	0.201
Lying bouts (n/d)	11.3	12.6	12.8	13.3	0.40	0.003	0.003
Lying time (h/d)	11.2	12.0	11.8	12.4	0.20	0.001	<0.001
Milk production (kg/d)	32.9	31.8	33.2	32.9	0.55	0.545	0.780

[1]Least squares means and SEM are presented. Treatments were applied within cow in a crossover design. The *P*-value for the linear term from models testing bedding weight (kg/stall) and compressibility (cm) are presented.

DISCUSSION

Cows spent more time lying down on well-bedded surfaces. This pattern was apparent for both shavings and straw when the bedding covered the entire surface of the tie-stall. For each additional kilogram of bedding, cows spent 3 and 12 min/d more time lying down for shavings and straw, respectively. These results support previous research on bedding levels in free-stalls (12-min increase in lying time for every addition 1 kg of sawdust; Tucker and Weary, 2004), indicating that additional bedding, at least above a certain level, improves the comfort of lying surfaces.

These results support previous studies that found that the amount of bedding influenced preferences for lying areas. For example, Jensen et al. (1988) showed that cows preferred stalls with concrete when they were bedded with 4 to 5 kg of straw, but over time, the animals switched their preferences to mattresses when little straw remained in the concrete stalls. Similarly, cows showed no differences in lying time when tested with concrete-based versus rubber-based stalls when both were bedded with 6.5 kg of straw (Manninen et al., 2002), but spent more time lying down in stalls with a rubber base versus a concrete base when these were covered with only 0.5 kg of straw (Rushen et al., 2007).

Additional bedding improved the compressibility of the surface, suggesting that this was an important factor underlying these changes in behavior. Indeed, the response to treatment was much more similar in the 2 experiments when treatments were expressed in terms of compressibility; for every 1-cm increase in compressibility of shavings, cows spent an additional 9 min lying in Exp. 1 and an additional 6 min lying in Exp. 2. These results are the first to demonstrate that lying time increases linearly with increasing compression of the stall surface.

In both Exp. 1 and 2, cows increased lying time by lying down more often. The difference in number of lying bouts was only statistically significant in Exp. 2, but the magnitude of the response (an increase of approximately 0.15 lying bouts/d for every additional 1 cm of compressibility) was similar in the 2 experiments, and a broader range of compressibility (2.2 to 14.6 cm) was tested in Exp. 2 compared with Exp. 1 (1.9 to 9.2 cm). It seems reasonable that bedding compressibility would affect the number of lying bouts because a cow places considerable weight on her knees during the transition from standing to lying. This pattern of lying down more often on softer surfaces is consistent with previous literature (Tucker and Weary, 2004).

Cow size, measured by BW, may influence the response to the bedding levels. For example, calves (4 to 21 wk old), unlike cows, show no difference in lying behavior when housed on concrete compared with rubber mats (Hanninen et al., 2005). We predicted that heavy cows might be affected more by the softness of the lying surface, particularly during the transition from standing to lying on the bedded surface. However, we found

Table 3. Cows kept in tie-stalls bedded with 0.5, 1, 2, or 3 kg of straw each morning (experiment 3)[1]

Item	Amount of straw (kg/stall) 0.5	1	2	3	SEM	P_{weight}	$P_{compressibility}$
Compressibility (cm)	2.2	2.2	4.4	6.7	—	—	—
Average lying bout (min/bout)	59	57	59	58	2.3	0.791	0.899
Lying bouts (n/d)	12.3	12.2	12.7	12.7	0.41	0.361	0.417
Lying time (h/d)	11.9	11.3	12.0	11.7	0.32	0.833	0.703
Milk production (kg/d)	33.0	33.4	32.8	32.9	0.33	0.482	0.397

[1]Least squares means and SEM are presented. Treatments were applied within cow in a crossover design. The *P*-value for the linear term from models testing bedding weight (kg/stall) and compressibility (cm) are presented.

no significant interactions between treatment and cow size. The range of BW tested was representative of lactating cattle (505 to 794 kg); including smaller or younger animals would improve the test of this idea.

The differences in total lying time between the highest and lowest levels of bedding (1.1 and 1.2 h/d, in Exp. 1 and 2, respectively) were similar to differences reported in comparisons of deep-bedded sawdust and mattresses in free-stalls (1.7 h/d; Tucker et al., 2003) and concrete and mattresses in tie-stalls (1.8 h/d; Haley et al., 2001). These differences in lying time were similar to the effect of removing the brisket board from the free stall (1.2 h/d; Tucker et al., 2006) or overstocking free-stalls by 50% (1.7 h/d; Fregonesi et al., 2007).

The biological significance of these differences in lying time is difficult to assess. In freestall systems, any increase in time spent in the stall seems desirable because it reduces time spent standing in the alleyway. Even a relatively small increase in time spent standing in the freestall (40 min/d) reduced lameness (Bernardi

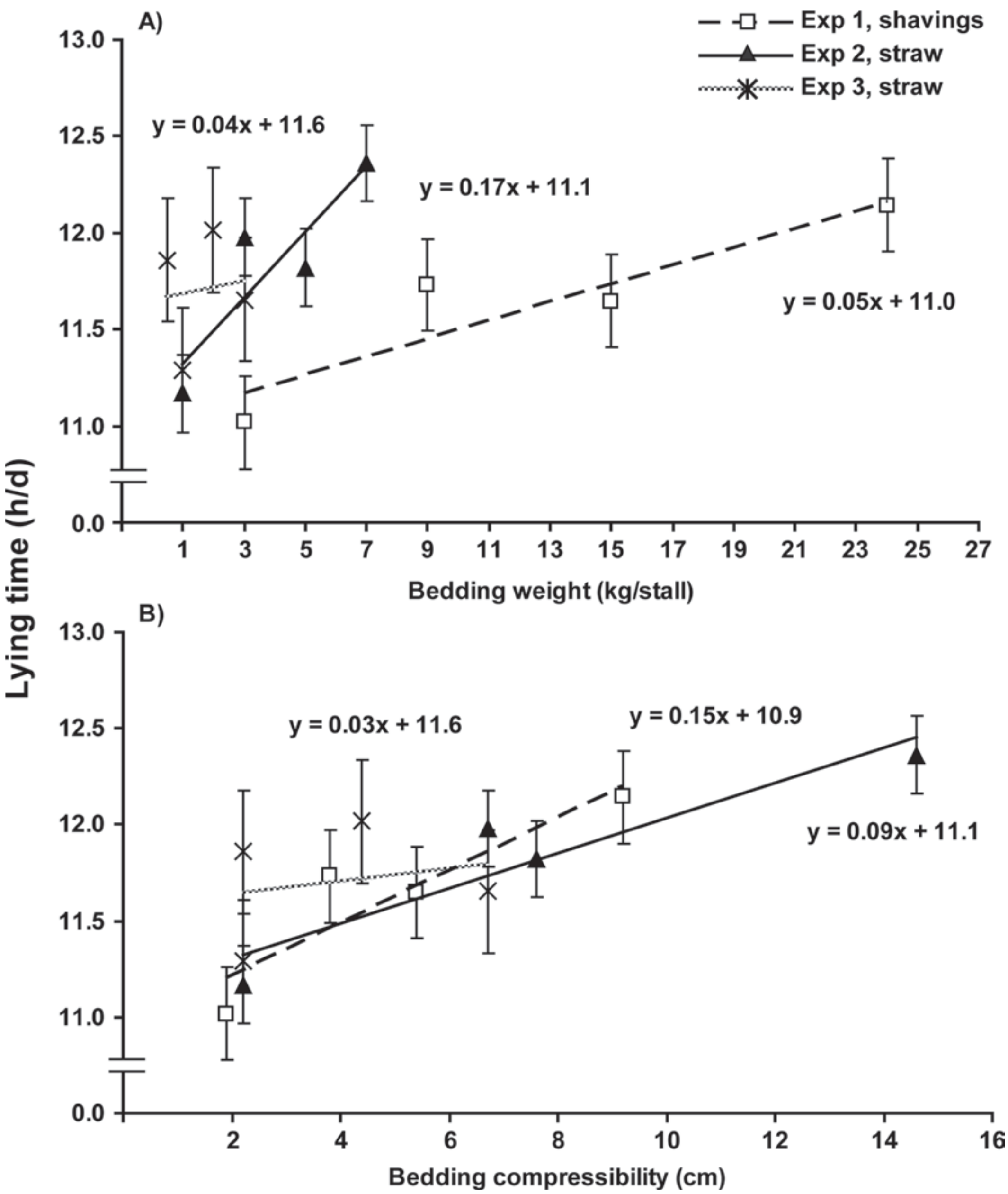

Figure 1. Lying time (h/d) in response to A) bedding weight and B) compressibility of shavings (experiment 1) or straw (experiments 2 and 3). Cows in experiments 1, 2, and 3 were lactating and kept in tie-stalls. The equation of the trend line (generated in Excel, Microsoft, Redmond, WA) is presented for each experiment. Least squares means and SEM are presented.

et al., 2009). The importance of small changes in lying time in other systems such as tie-stalls or pasture, where the alternative is standing on a dry, soft surface, is less clear. Only 1 average lying time, 11.1 h/d in the 1-kg straw treatment in Exp. 2, fell below the 12 to 13 h/d threshold for lying time identified by Jensen et al. (2005). Longer term work is required to assess the effects of these higher lying times on cow health or well-being in tie-stall systems.

These results indicated that the addition of straw or shavings improved cow comfort while lying but provided little direction about which material is preferable. Earlier work suggests that beef cattle prefer straw to sawdust, but no information was provided about the amount of bedding used in each treatment (Lowe et al., 2001). This information is particularly important in light of our finding that there was no difference in lying behavior associated with low levels of straw, <3 kg over a 2.4-m^2 area. The low levels of straw tested in Exp. 3 (0.5, 1, 2, and 3 kg/stall) covered the entire stall surface but provided little increase in compressibility (2.2, 2.2, 4.4, 6.7 cm, respectively). It is important to note that other physical properties of bedding such as insulation may affect lying behavior and preferences for stall surfaces. For example, cattle prefer polyethylene vinyl acetate mats in cooler conditions, but prefer shavings when the temperature-humidity index exceeds 80 (De Palo et al., 2006). In contrast, cattle preferred straw and rubber mats to sand in both summer and winter in Finland (Manninen et al., 2002). Although this issue was not explored directly in the current study, differences in thermal conductance between bedding type may play a role in the decision of which material to use. Finally, several other factors including bacterial growth (Godden et al., 2008), ammonia emissions (Powell et al., 2008), and cost are likely to affect producers' decision about what bedding to use.

None of the bedding types or levels had any effect on milk production. These experiments were designed to test behavioral effects, and the duration of each treatment (1 wk) was too short to meaningfully test differences in milk production. Other studies with similar differences in lying time (0.7 h/d between stalls measuring 106 and 126 cm), conducted with 3-wk treatment periods, reported no significant differences in milk production (Tucker et al., 2004). We speculate that changes in lying time were not associated with milk production because DMI, a limiting factor for milk production, was not affected by the treatments tested. Other variables such as health and longevity are likely more important when assessing the economic importance of cow comfort. For example, dairy cattle kept in deep-bedded sand systems were less lame and these farms tended to have a lower cow replacement rate compared with farms using mattresses (Cook et al., 2004). Thus, it seems likely that cow comfort in the lying area affects profitability, but long-term measures are needed to quantify these benefits.

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